# Planetary Entry Probes and Mass Spectroscopy:

## Tools and science results from in situ studies of planetary atmospheres and surfaces.

Invited Talk for the First Annual Alvin Seiff Award

by
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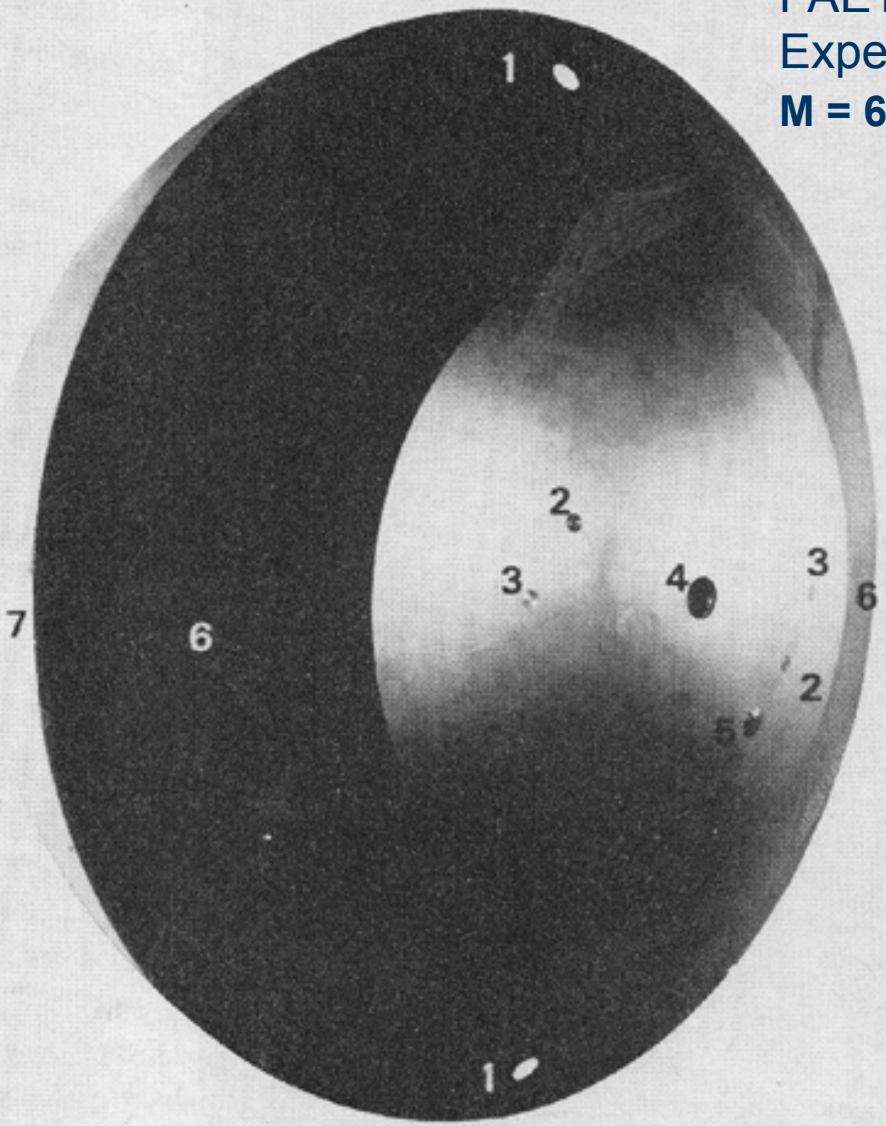
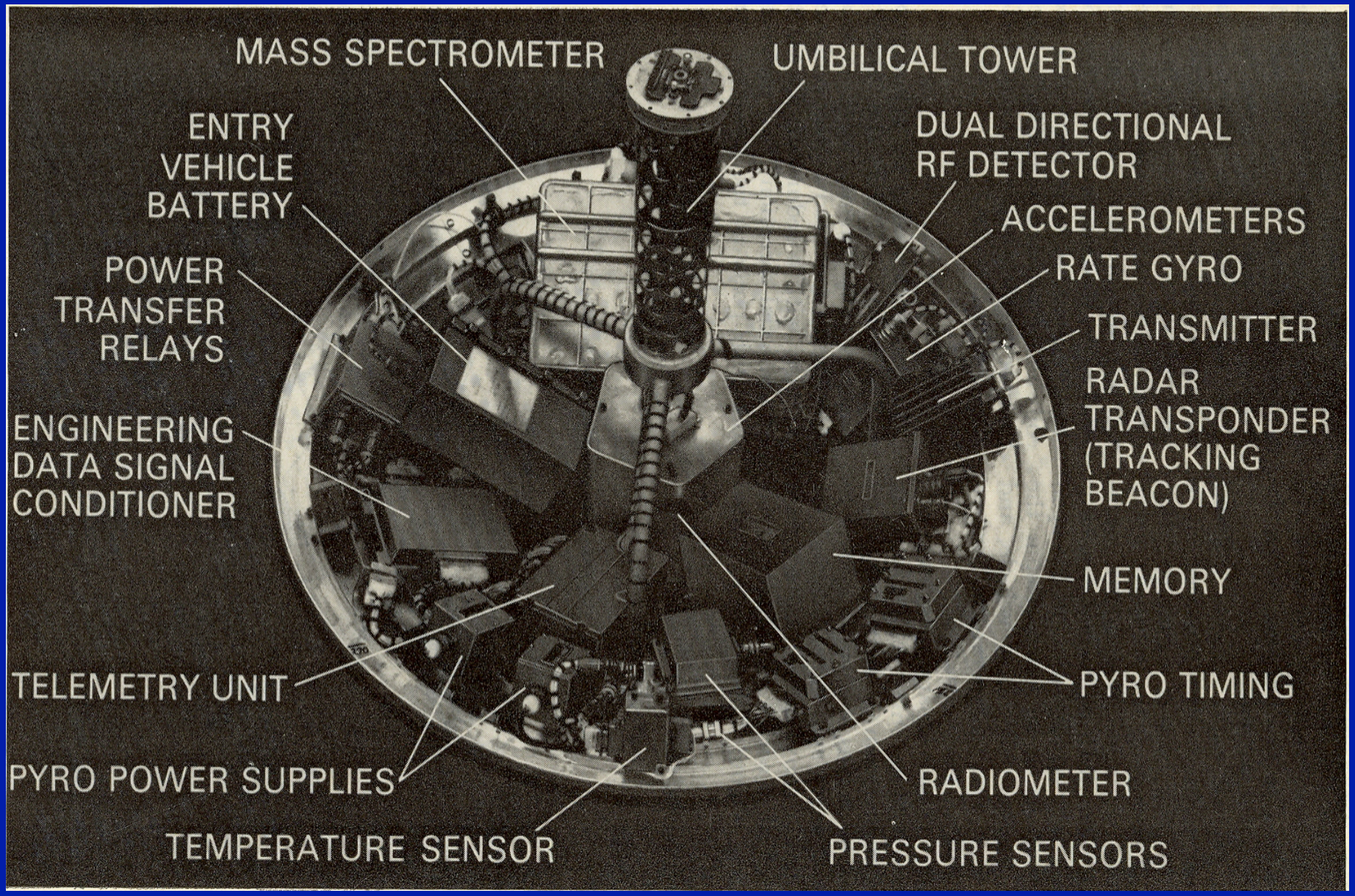
# Al Seiff's Heritage

PAET (1971), An Entry Probe Experiment in the Earth's Atmosphere

**M = 62 kg, $M_{inst}$ = 14 Kg, D = .914 m**

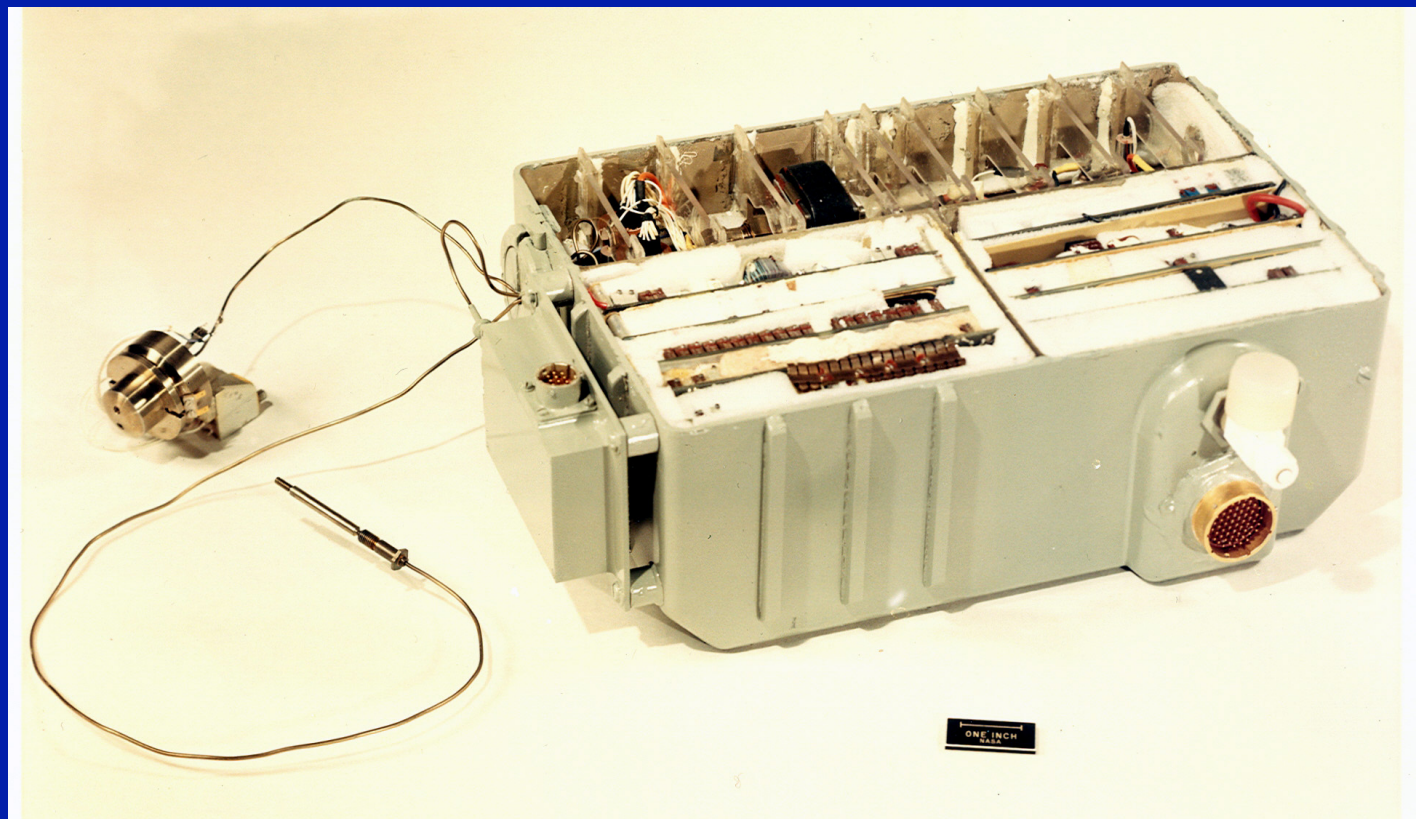



1 AMBIENT TEMPERATURE PROBES
2 PRESSURE PORTS
3 HEAT TRANSFER SENSORS
4 RADIOMETER WINDOW
5 MASS SPECTROMETER INLET
6 HEAT SHIELD PLUGS
7 AFTERBODY HEAT SHIELD TEMPERATURE SENSOR


MASS SPECTROMETER
UMBILICAL TOWER
ENTRY VEHICLE BATTERY
DUAL DIRECTIONAL RF DETECTOR
ACCELEROMETERS
RATE GYRO
POWER TRANSFER RELAYS
TRANSMITTER
RADAR TRANSPONDER (TRACKING BEACON)
ENGINEERING DATA SIGNAL CONDITIONER
MEMORY
TELEMETRY UNIT
PYRO TIMING
PYRO POWER SUPPLIES
RADIOMETER
TEMPERATURE SENSOR
PRESSURE SENSORS

# PAET Mass spectrometer

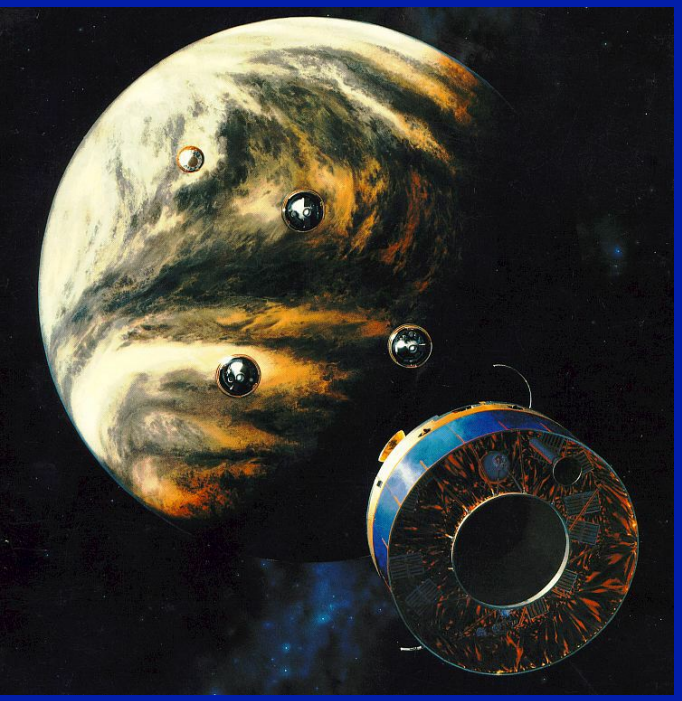
- Launch: June 20, 1971
- First entry probe mass spectrometer
- Quadrupole analyzer, electron impact ionization source, secondary electron multiplier ion detector
- Mass: 7.9 Kg
- Mass Range:
  10-90 amu



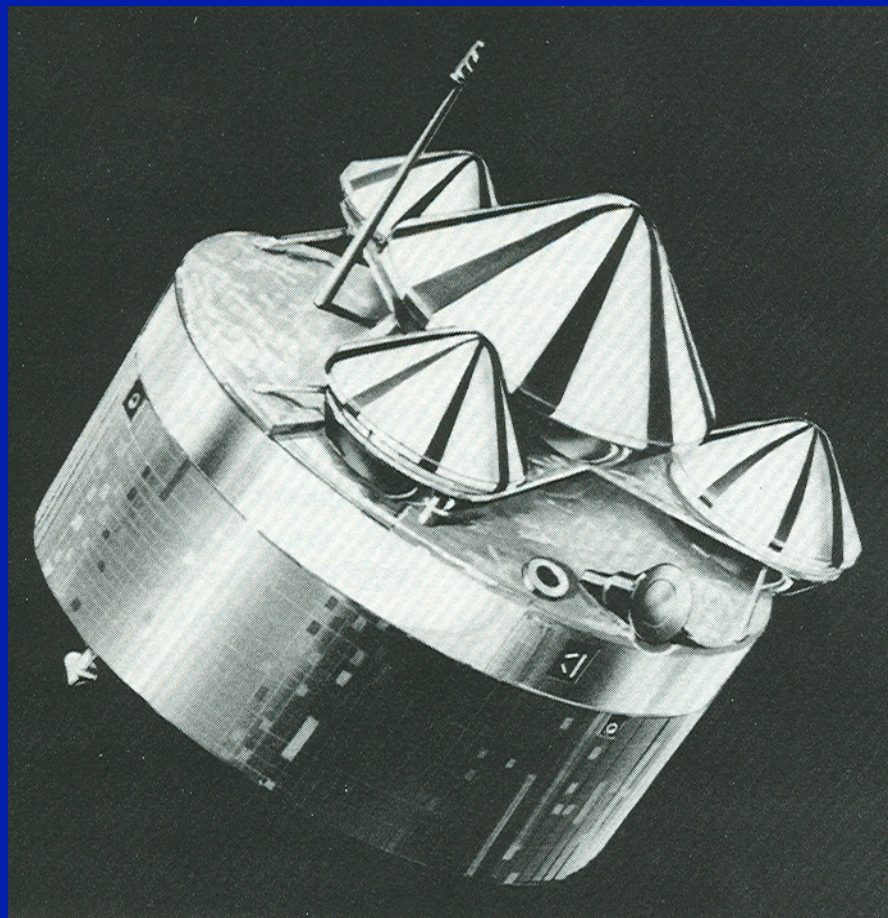
# Past Missions

- PAET: June 1971
- Venera 9 and 10: October 1975
- Viking 1 and 2: July and September 1976
- Pioneer Venus Multiprobe: December 1978
- Venera 11 and 12: December 1978
- Venera 13 and 14: March 1982
- Vega 1 and 2: June 1985
- Galileo Probe: December 1995
- Cassini-Huygens Probe: January 2005

# Pioneer Venus Multiprobe



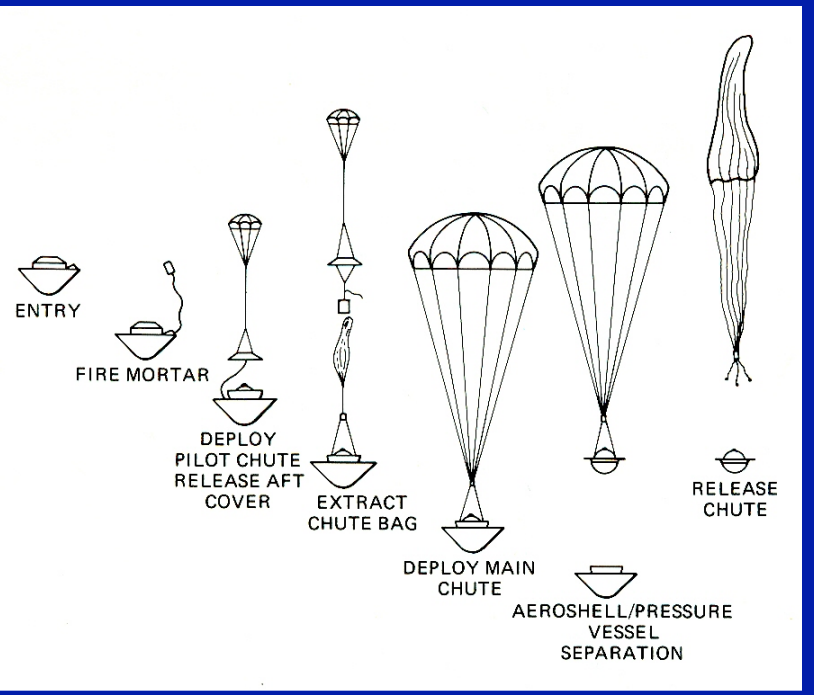
- Launched August 8, 1978
- Consisted of a large probe, 3 small probes, and the instrumented bus



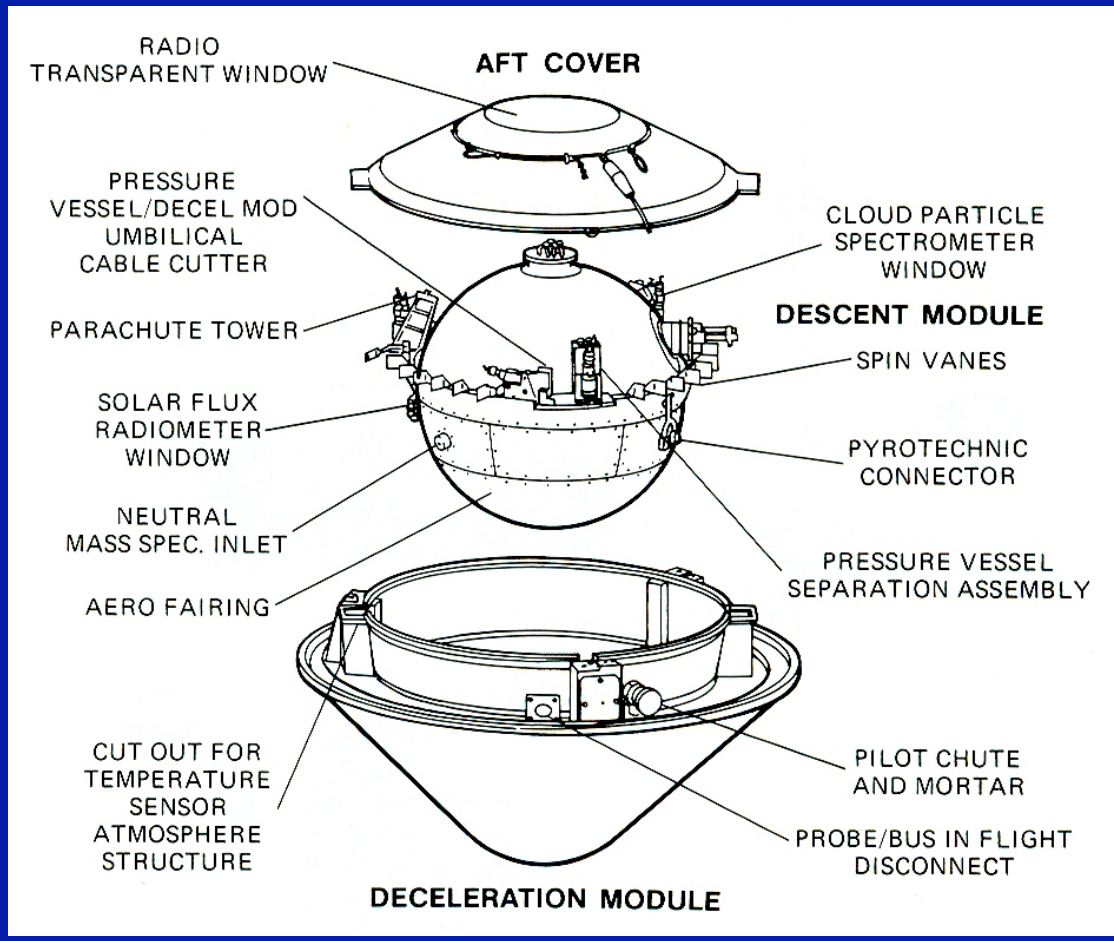
- Small probes released November 16, 1978
- Large probe released November 20, 1978
- Atmospheric entry of probes and bus on December 9, 1978

# Pioneer Venus Large Probe

- 315 kg, 1.5 m diameter,7 experiments
- Gas Chromatograph, PI Vance I. Oyama
- Neutral Particle Mass Spectrometer, PI John D. Hoffman

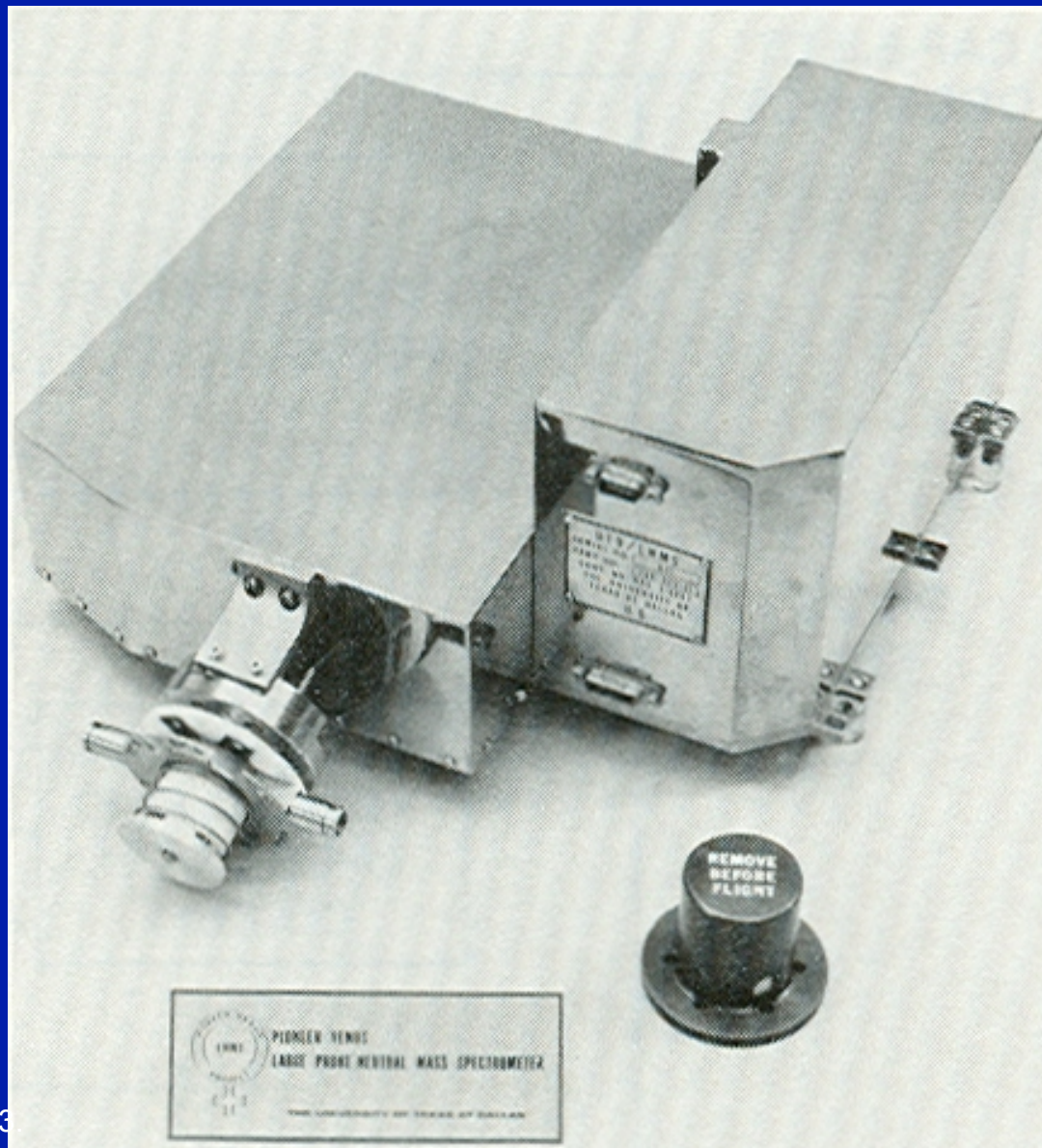



Fimmel, R., Colin, L., Burgess, E., *Pioneer Venus*, NASA SP-461, 1983.



# Large Probe Neutral Particle Mass Spectrometer (LNMS)

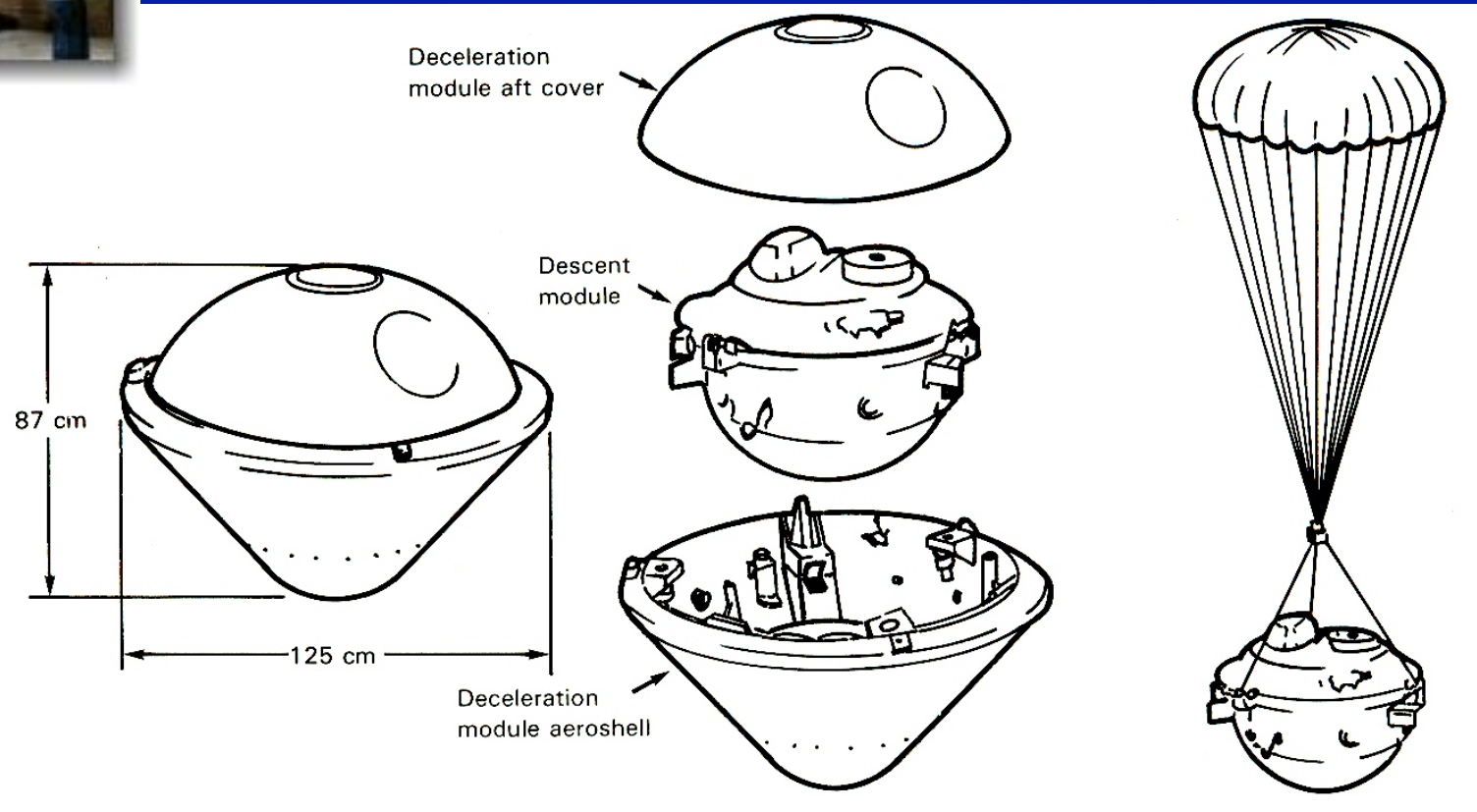
- Double-focusing magnetic deflection mass spectrometer
- Ceramic micro-leak gas inlet
- Mass range: 1 to 212 u
- Dynamic range: $1 \times 10^7$
- Mass: 9 kg
- Average Power: 12 W



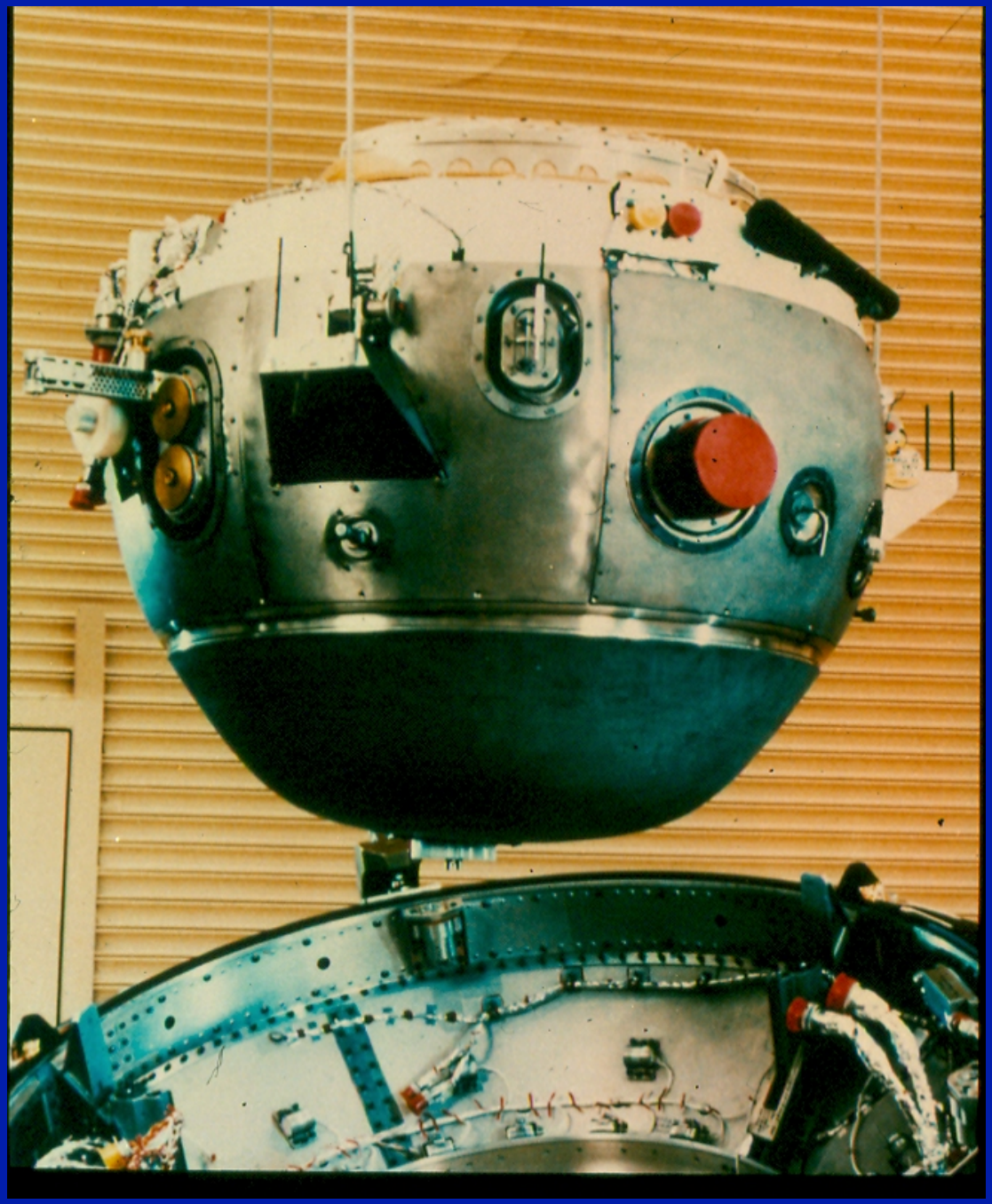

Fimmel, R., Colin, L., Burgess, E., *Pioneer Venus*, NASA SP-461, 1983

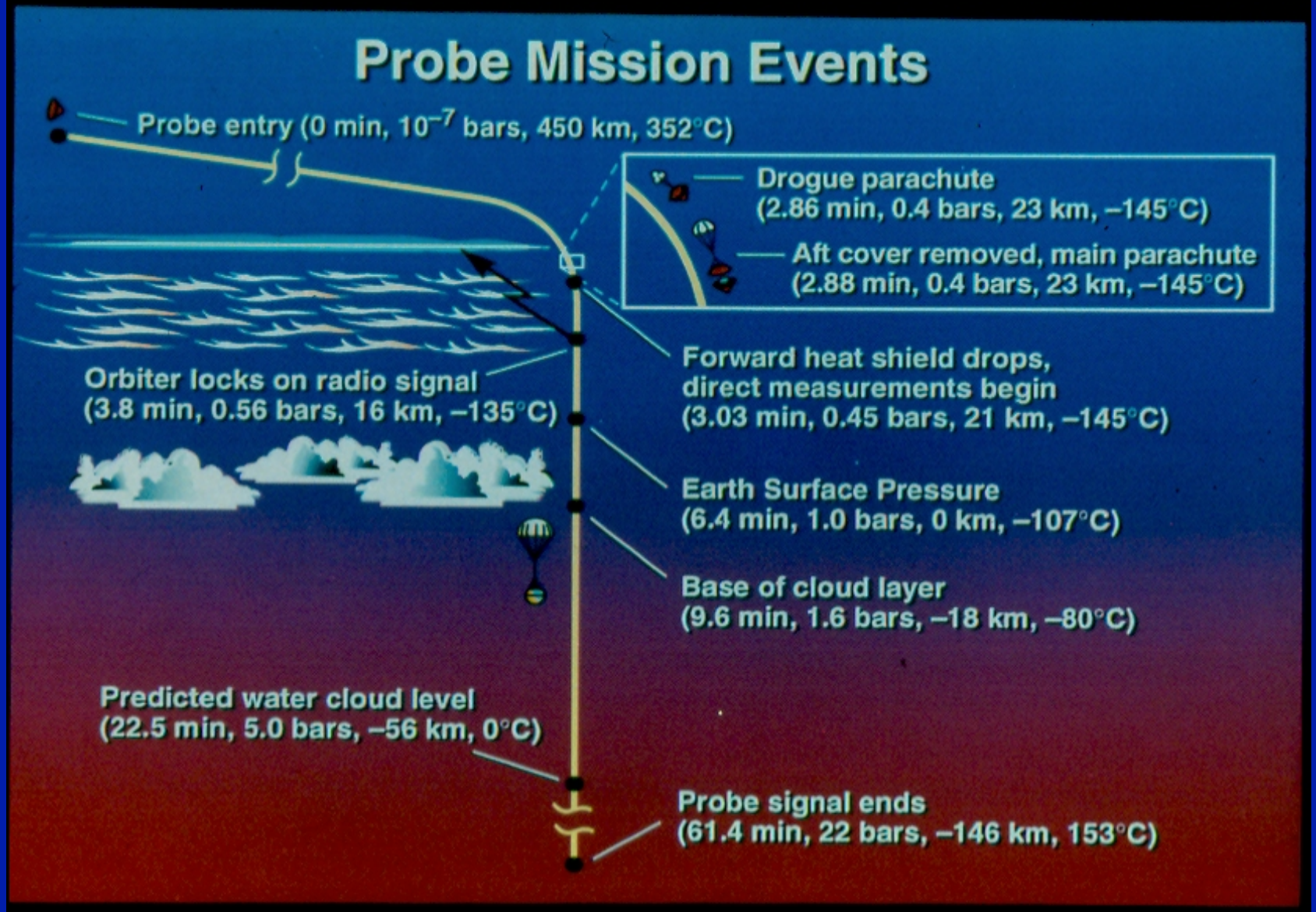
# Galileo Probe at Jupiter

- Launch: October 18, 1989
- Entry: December 7, 1995
- Probe mass: 340 kg
- 6 experiments
- Descent lasted 58 minutes (0.4 to 23 bar)



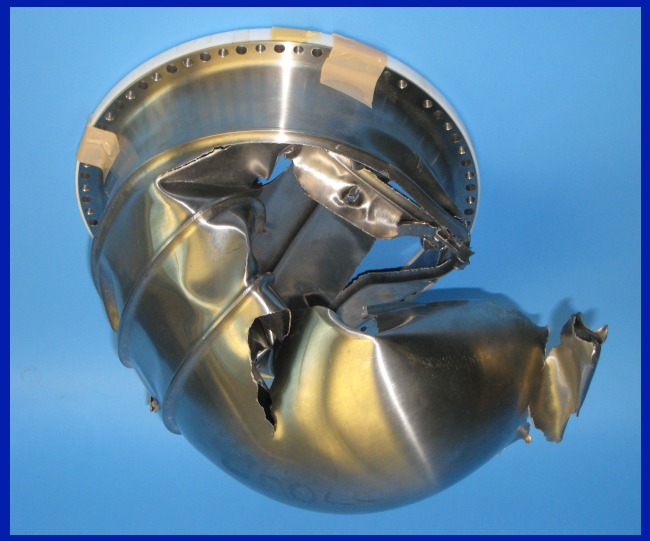

Yeates, C., Johnson, T., Colin, L., Fanale, F., Frank, L., Hunten, D., *Galileo: Exploration of Jupiter's System*, NASA SP-479, 1985.



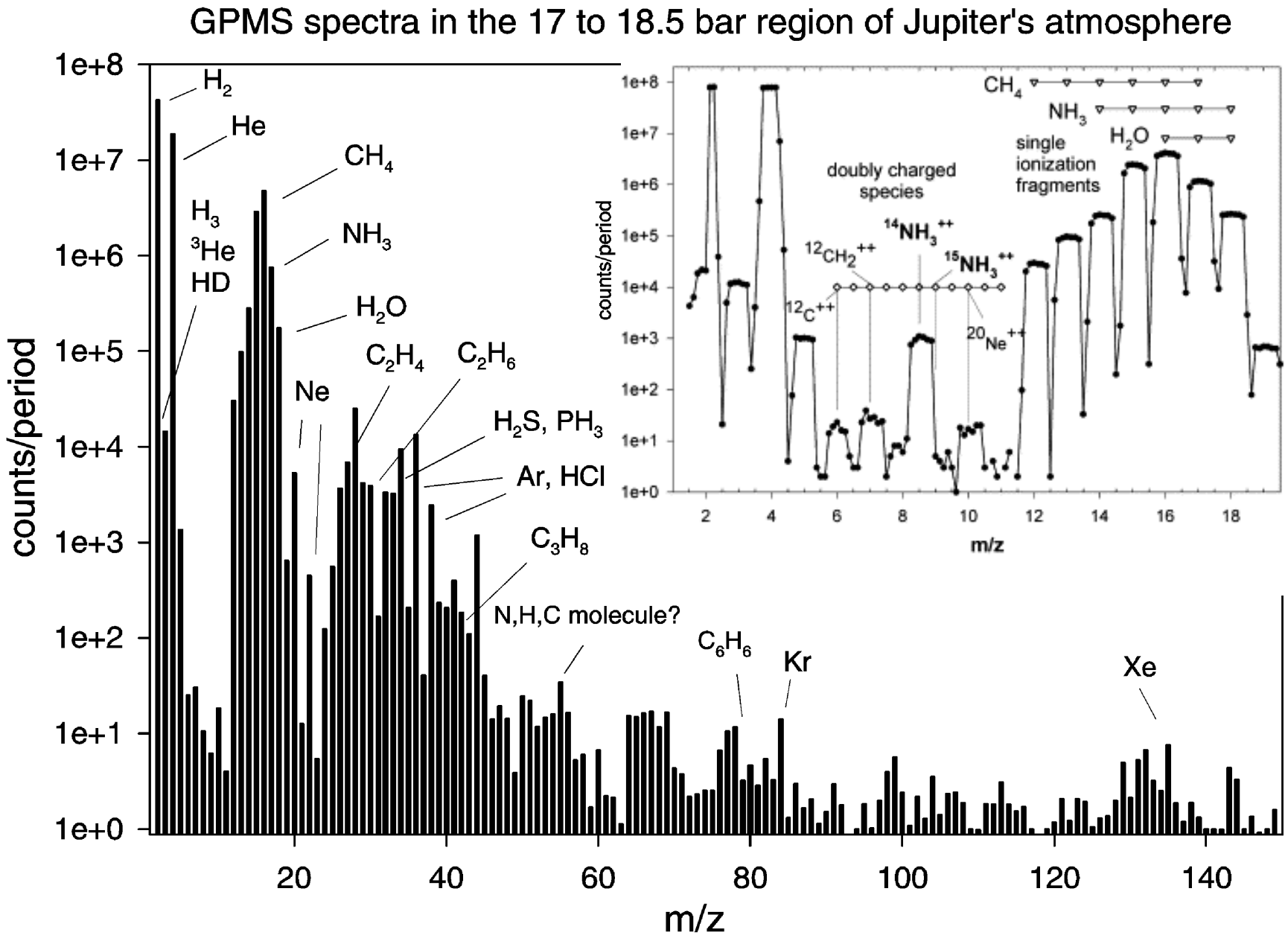

Probe Mission Events
Probe entry (0 min, 10$^{-7}$ bars, 450 km, 352°C)
Drogue parachute
(2.86 min, 0.4 bars, 23 km, –145°C)
Aft cover removed, main parachute
(2.88 min, 0.4 bars, 23 km, –145°C)
Forward heat shield drops,
direct measurements begin
(3.03 min, 0.45 bars, 21 km, –145°C)
Orbiter locks on radio signal
(3.8 min, 0.56 bars, 16 km, –135°C)
Earth Surface Pressure
(6.4 min, 1.0 bars, 0 km, –107°C)
Base of cloud layer
(9.6 min, 1.6 bars, –18 km, –80°C)
Predicted water cloud level
(22.5 min, 5.0 bars, –56 km, 0°C)
Probe signal ends
(61.4 min, 22 bars, –146 km, 153°C)

# Galileo Probe Mass Spectrometer (GPMS)

- Quadrupole sensor with 2 electron impact filaments
- Sample trapping and enrichment system
- Mass range 1-150 u
- Mass: 13.2 kg
- Average Power: 22 Watt

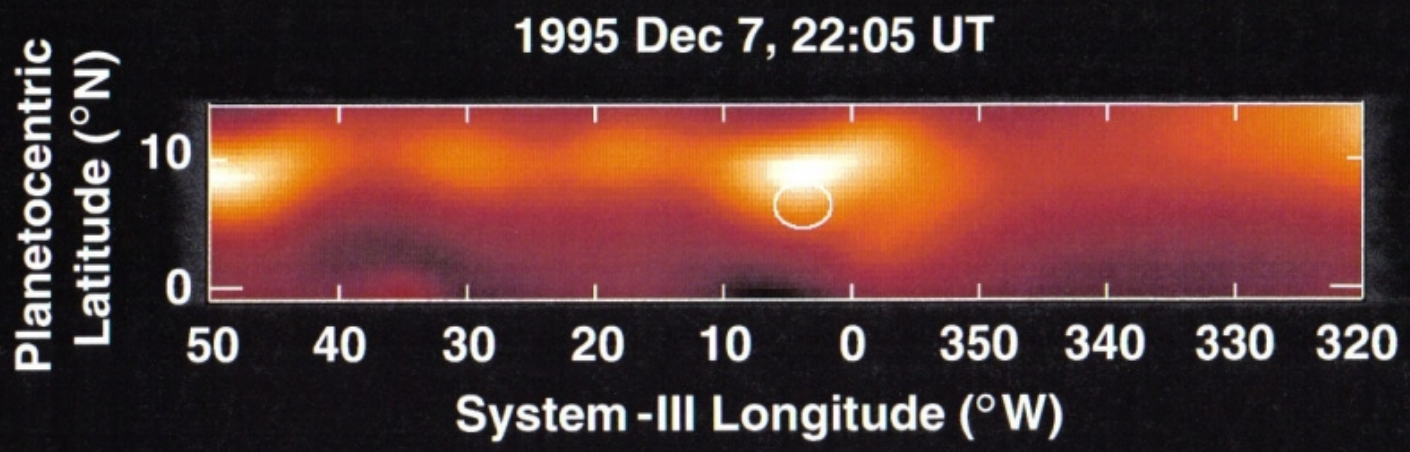


GALILEO PROBE MASS SPECTROMETER (GPMS)

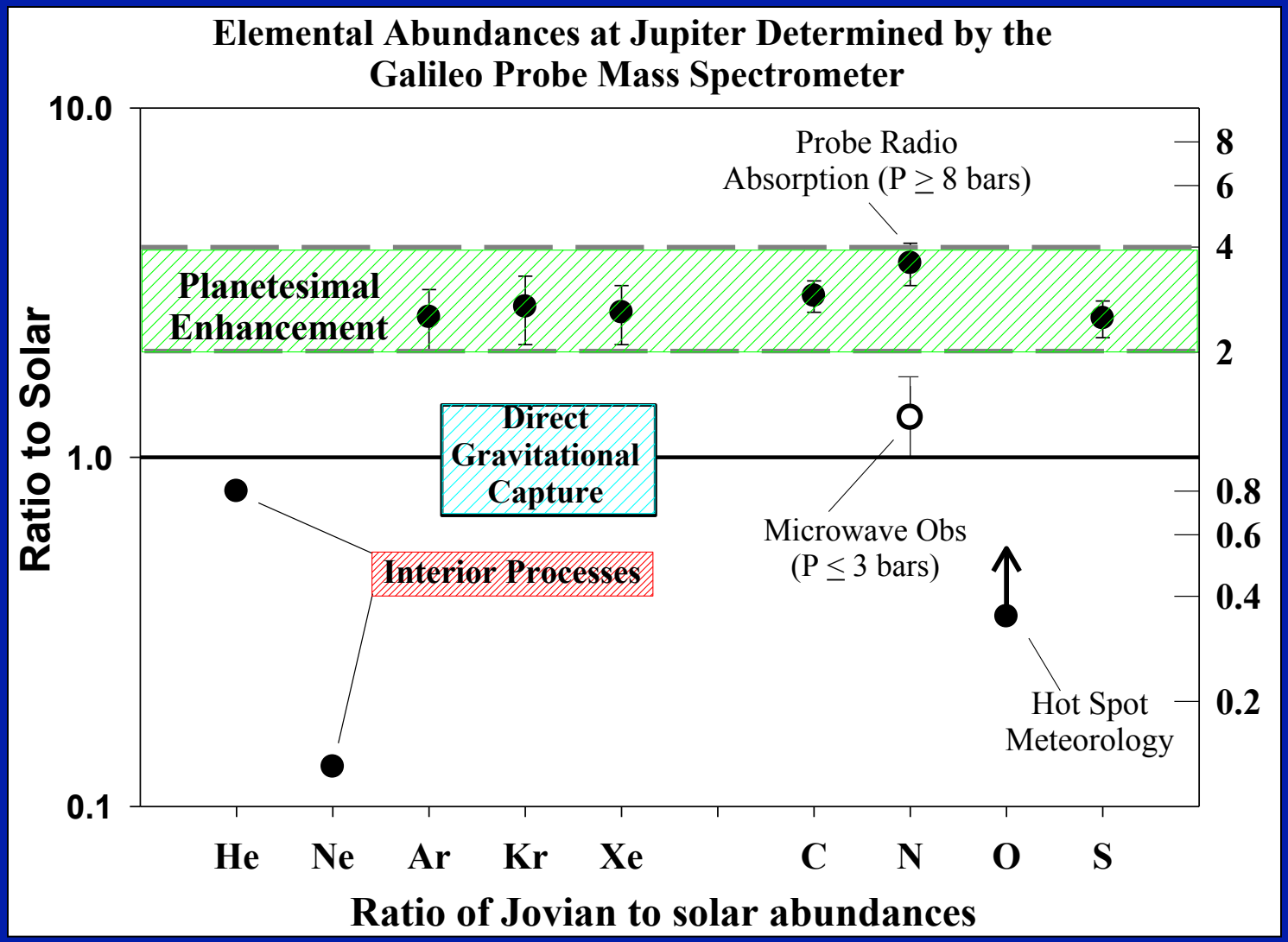

GPMS spectra in the 17 to 18.5 bar region of Jupiter's atmosphere
counts/period
m/z
H2
He
CH4
H3
3He
HD
NH3
H2O
C2H4
C2H6
Ne
H2S, PH3
Ar, HCl
C3H8
N,H,C molecule?
C6H6
Kr
Xe
CH4
NH3
H2O
single ionization fragments
doubly charged species
12CH2++
14NH3++
15NH3++
12C++
20Ne++

# Cylindrical Maps of Jupiter: 1° S – 14° N

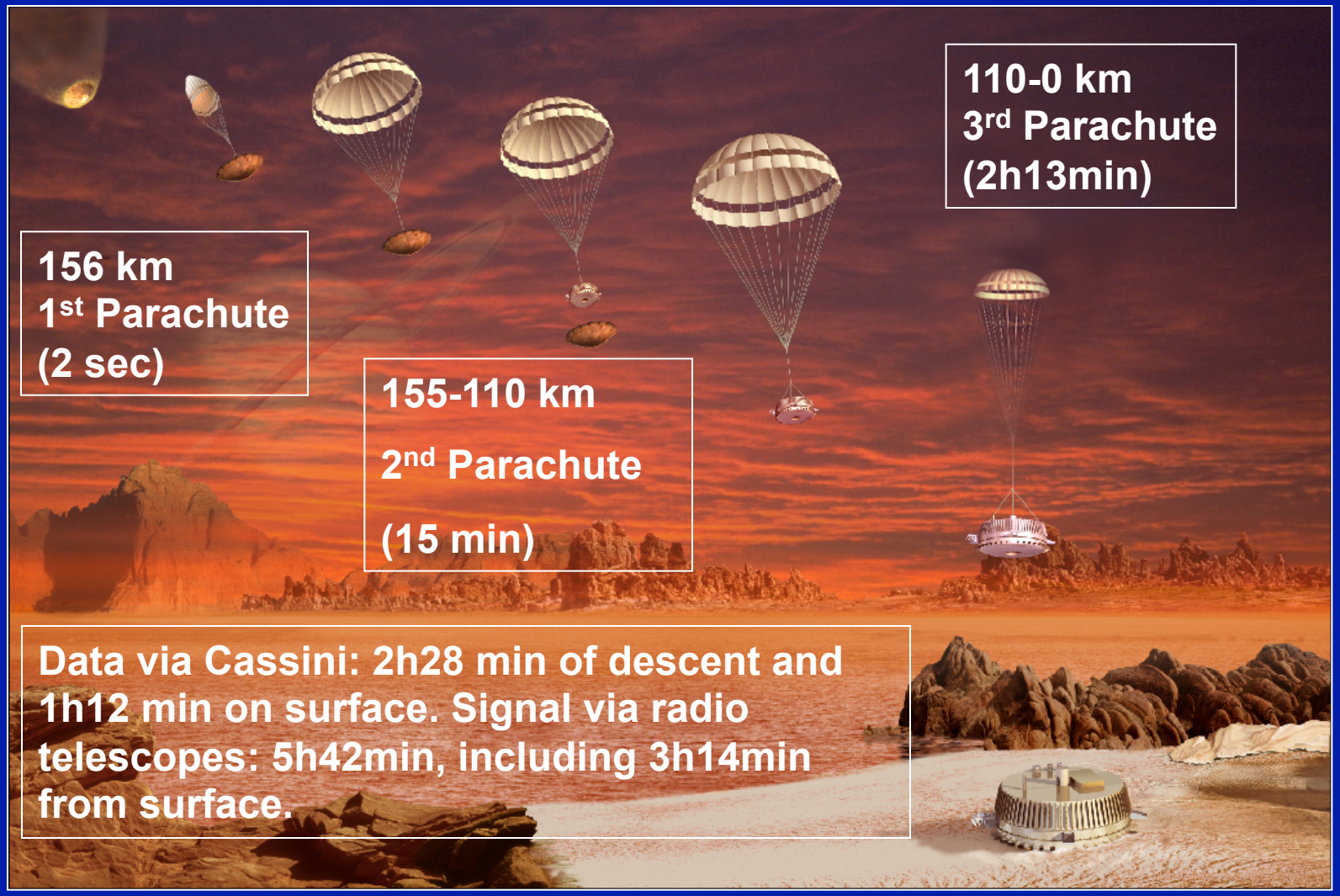
## NASA Infrared Telescope Facility
## Middle Infrared Array Camera: 4.8μm



# Elememtal abundances in Jupiter's atmosphere



# Huygens Descent and Landing Overview



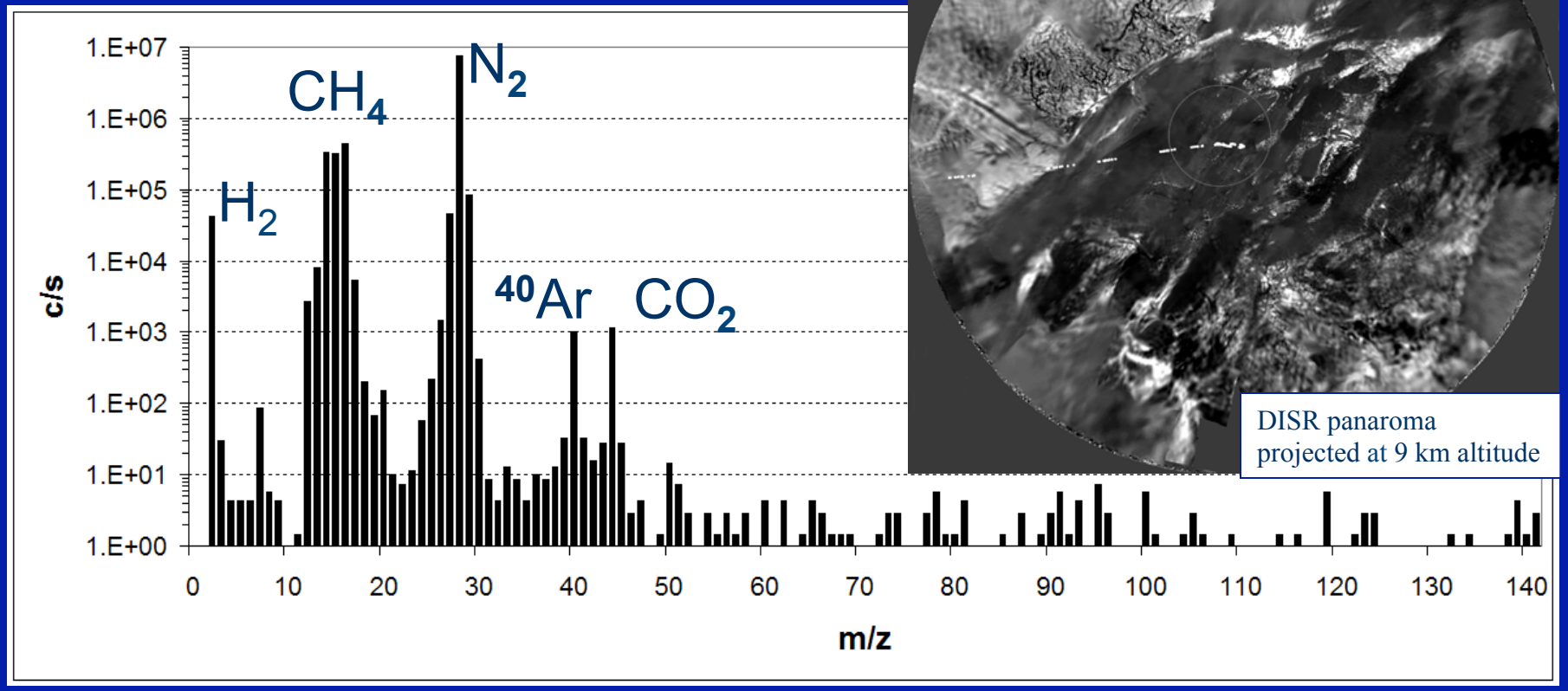
Top Hat
Outlet
LABEN
LABEN

# Huygens Probe Gas Chromatograph Mass Spectrometer

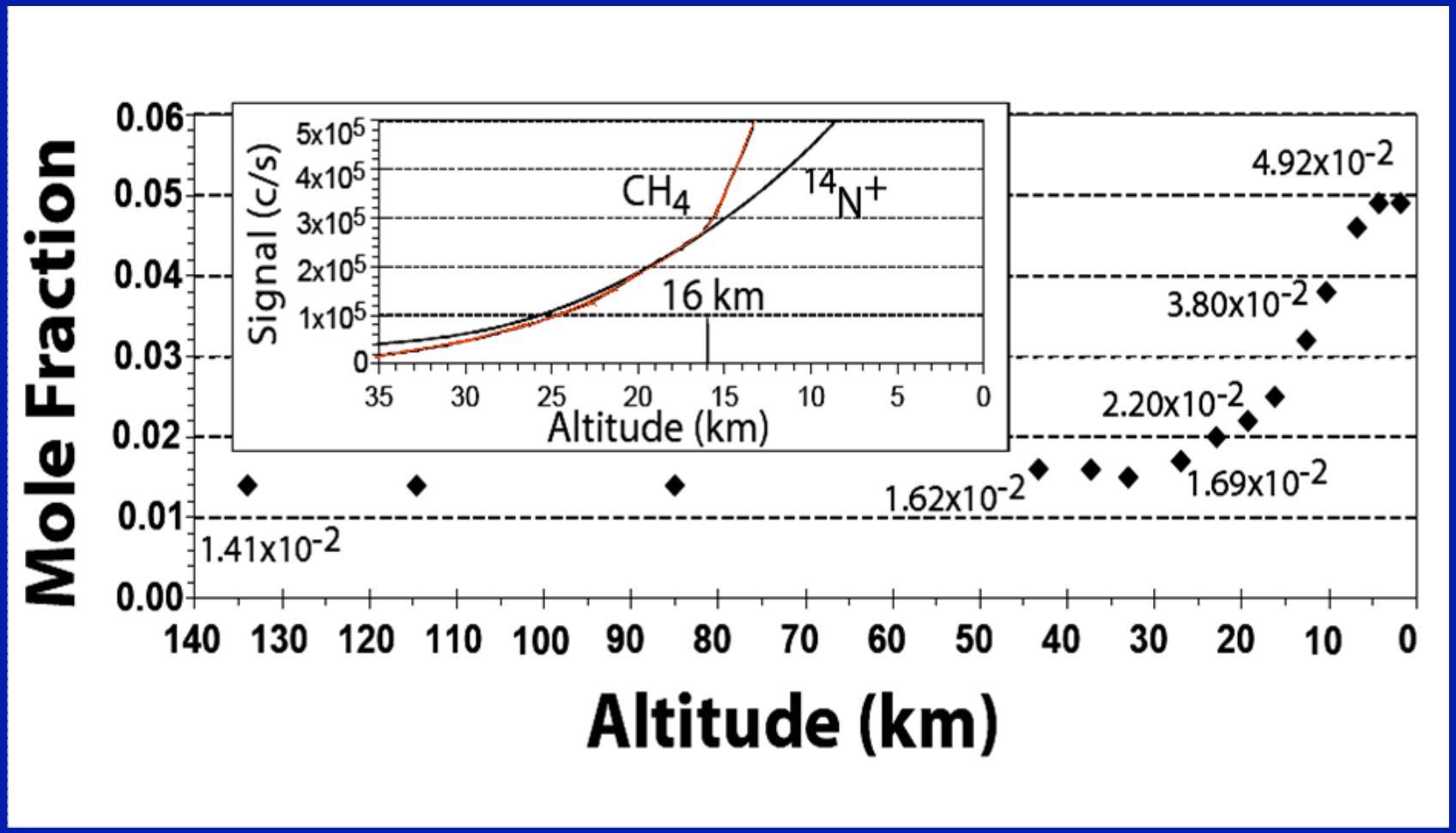
**First Meeting of the Huygens Science Working Team**

**December 13, 1990, Jet Propulsion Laboratory**

# Lower Atmosphere Averaged Spectrum (20-10 km)



# Methane mole fraction



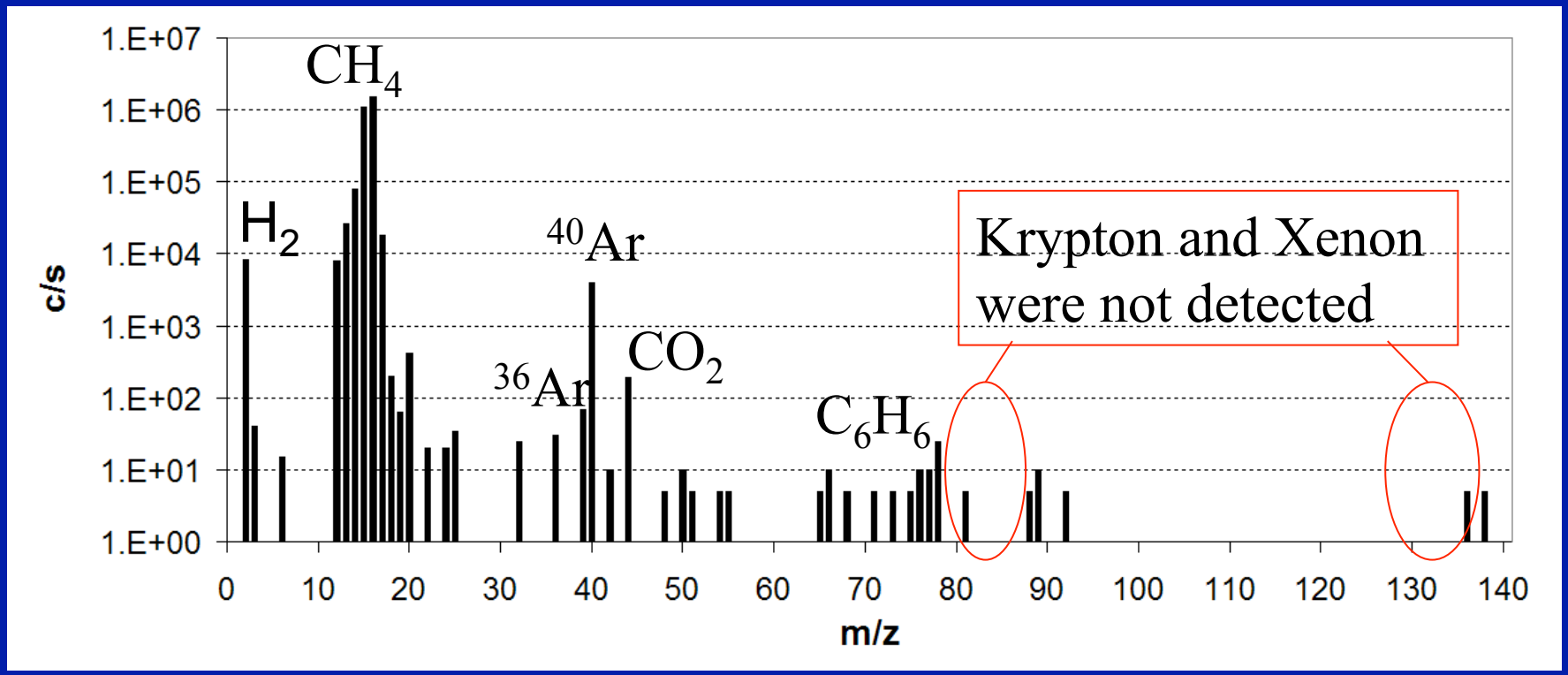

(Niemann et al., Nature, 438, 779-784, 2005)

# Noble Gases

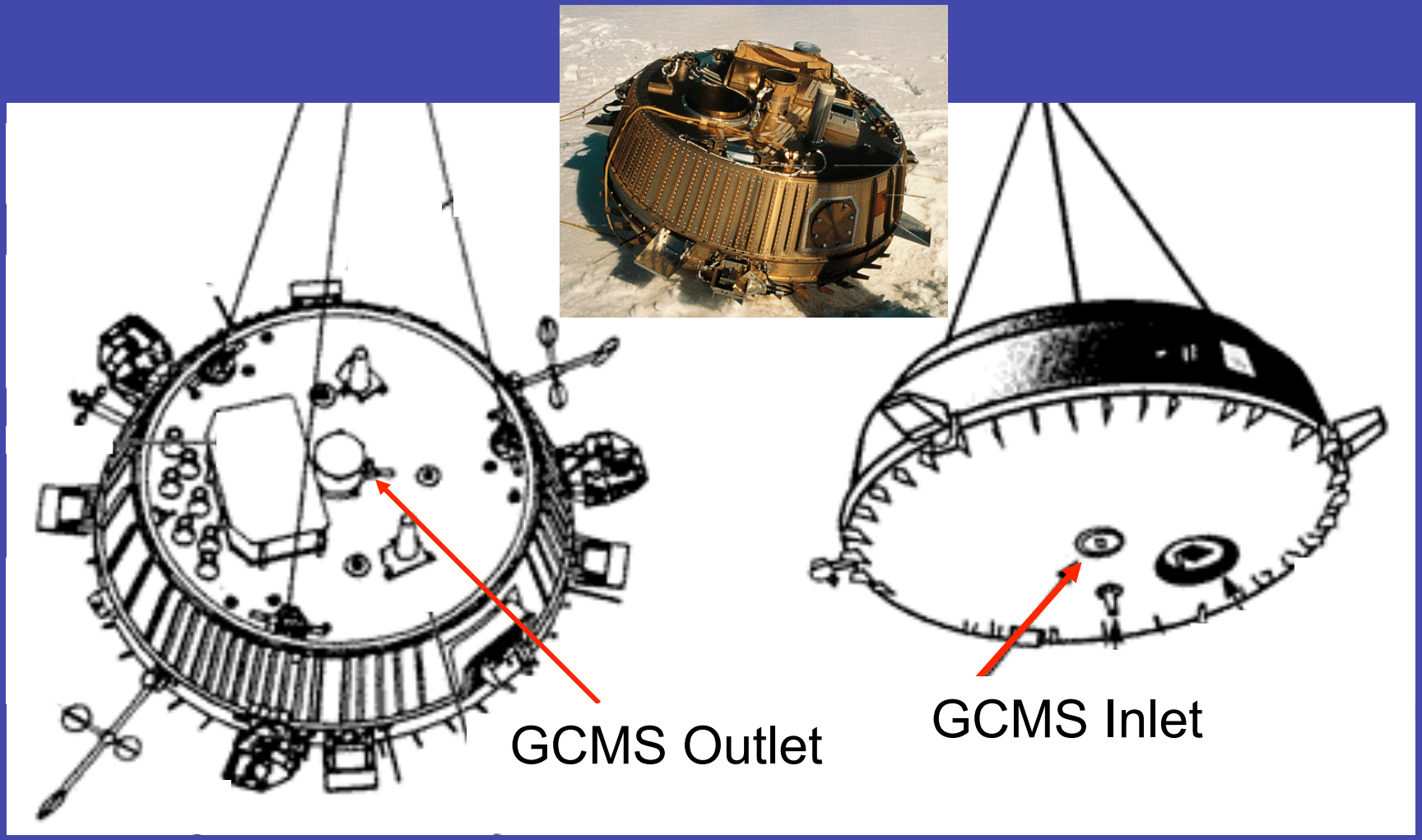
Primordial argon 36,($^{36}Ar$),was detected

in the Rare Gas Cell: Mole fraction $(2.2\pm.5)\times10^{-7}$.

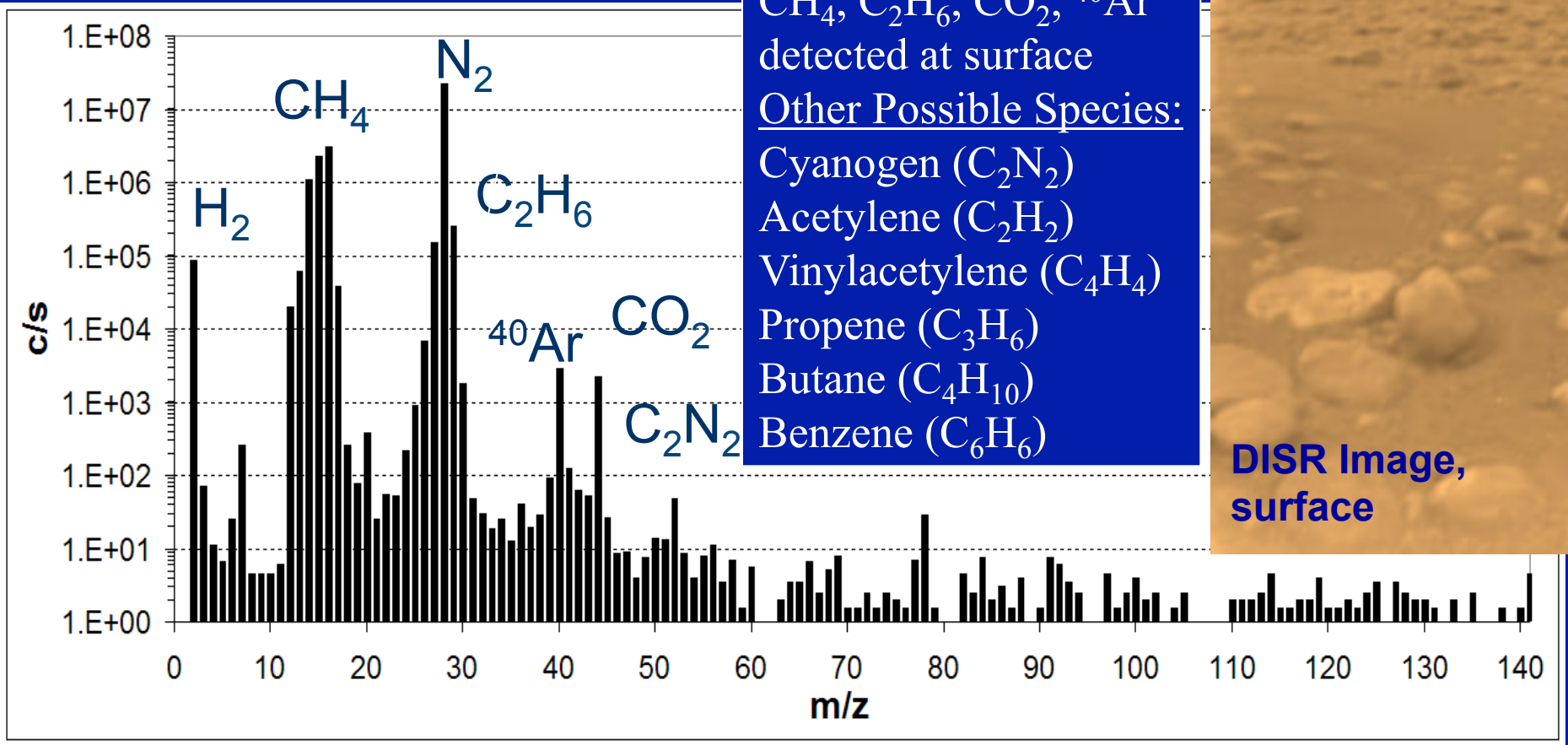
Mole fractions of krypton and xenon are below 10 ppb



# Atmosphere Inlet and Outlet Locations



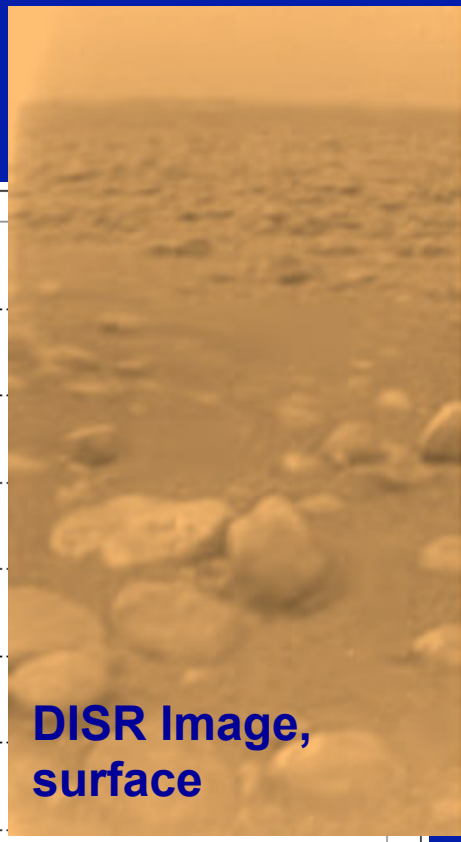
# Averaged Surface Spectrum




$CH_4$, $C_2H_6$, $CO_2$, $^{40}Ar$ detected at surface

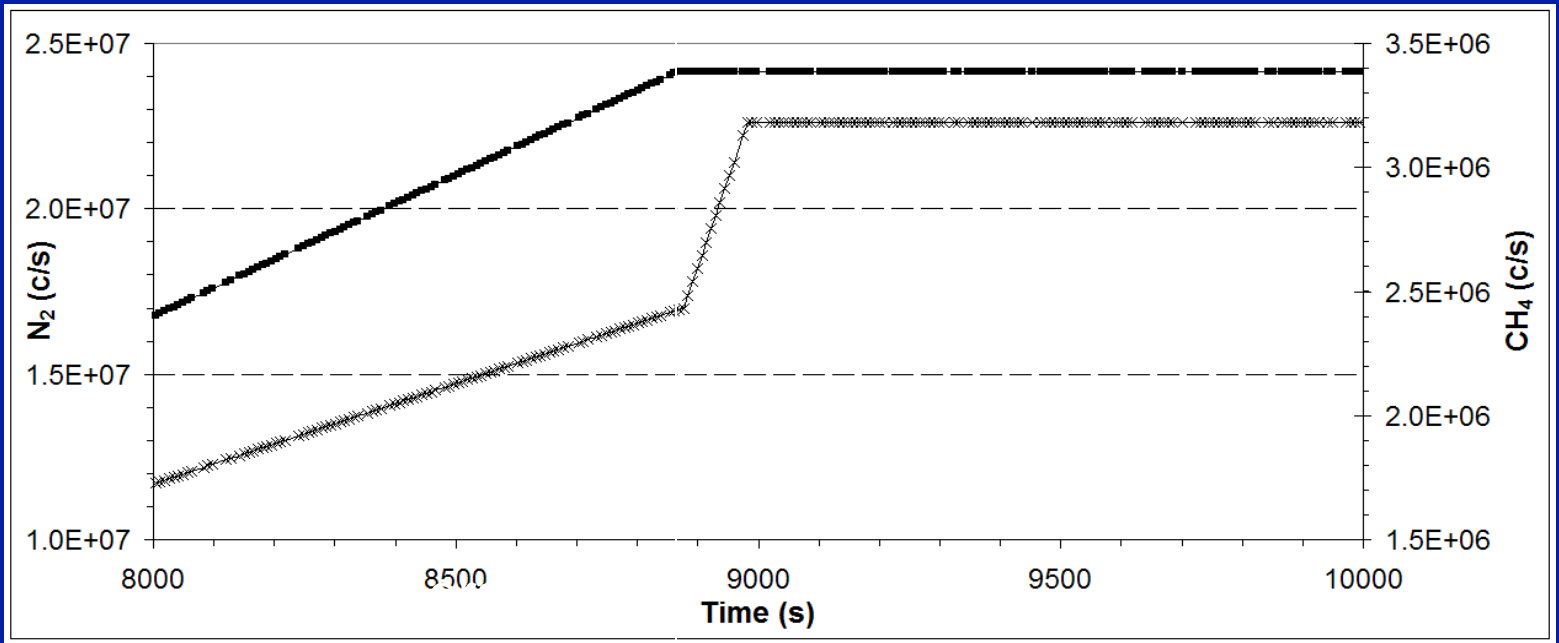
<u>Other Possible Species:</u>

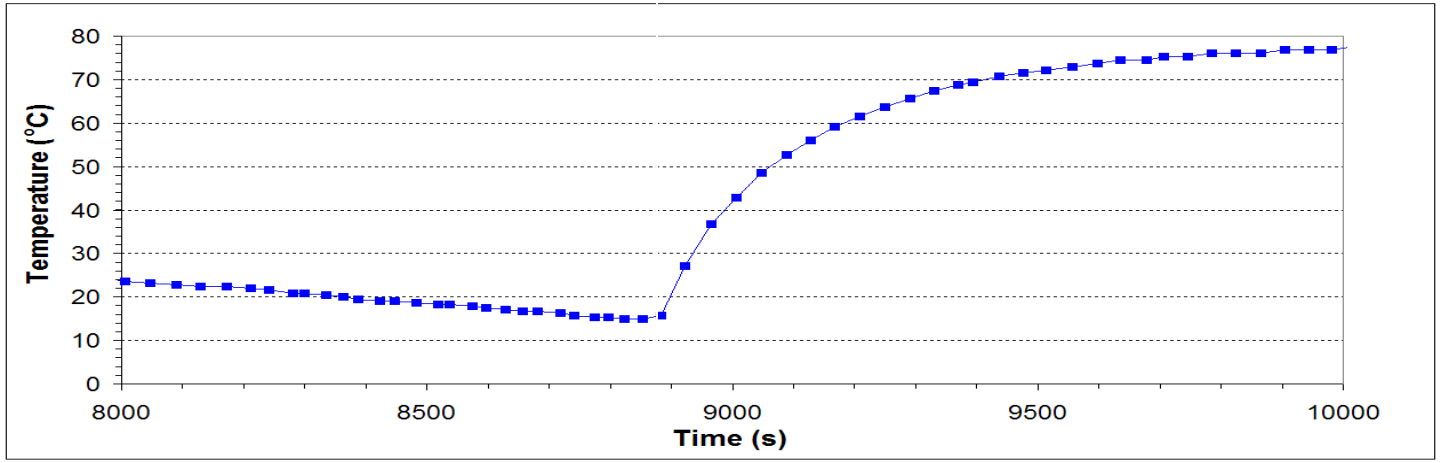
Cyanogen ($C_2N_2$)
Acetylene ($C_2H_2$)
Vinylacetylene ($C_4H_4$)
Propene ($C_3H_6$)
Butane ($C_4H_{10}$)
Benzene ($C_6H_6$)



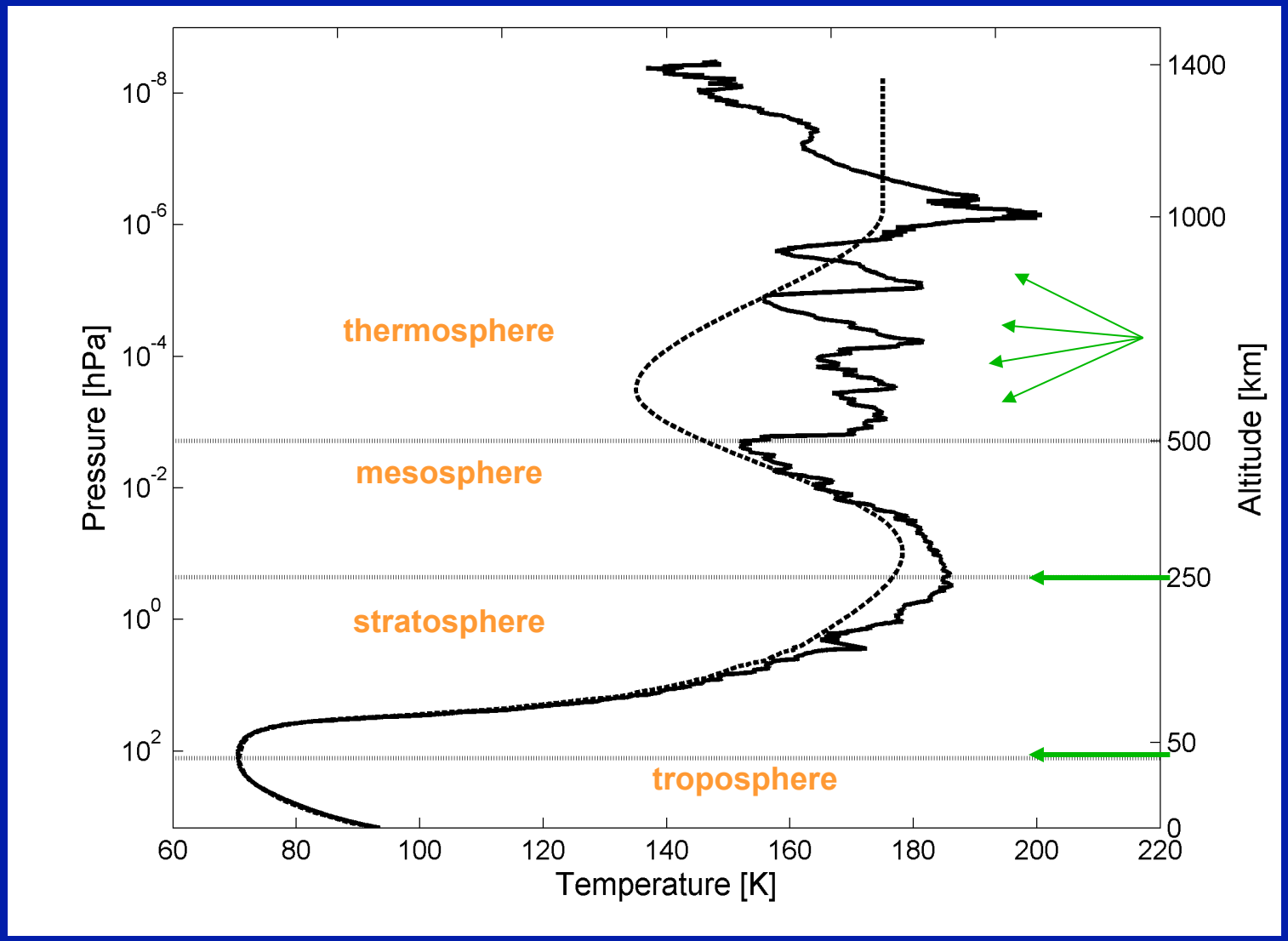
**DISR Image, surface**

# Surface Response of $N_2$ and $CH_4$



# HASI temperature profile

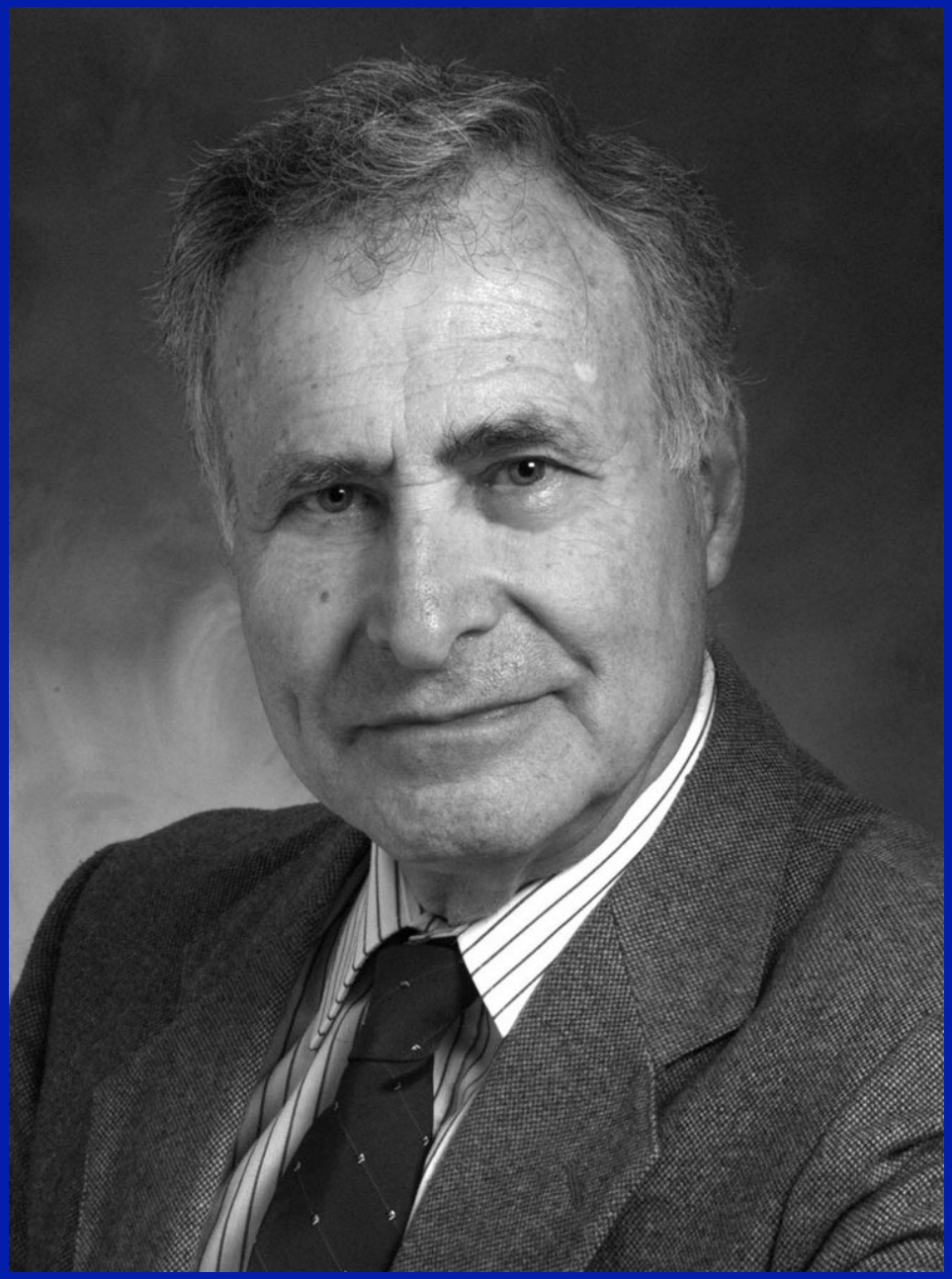



inversion layers

stratopause

tropopause

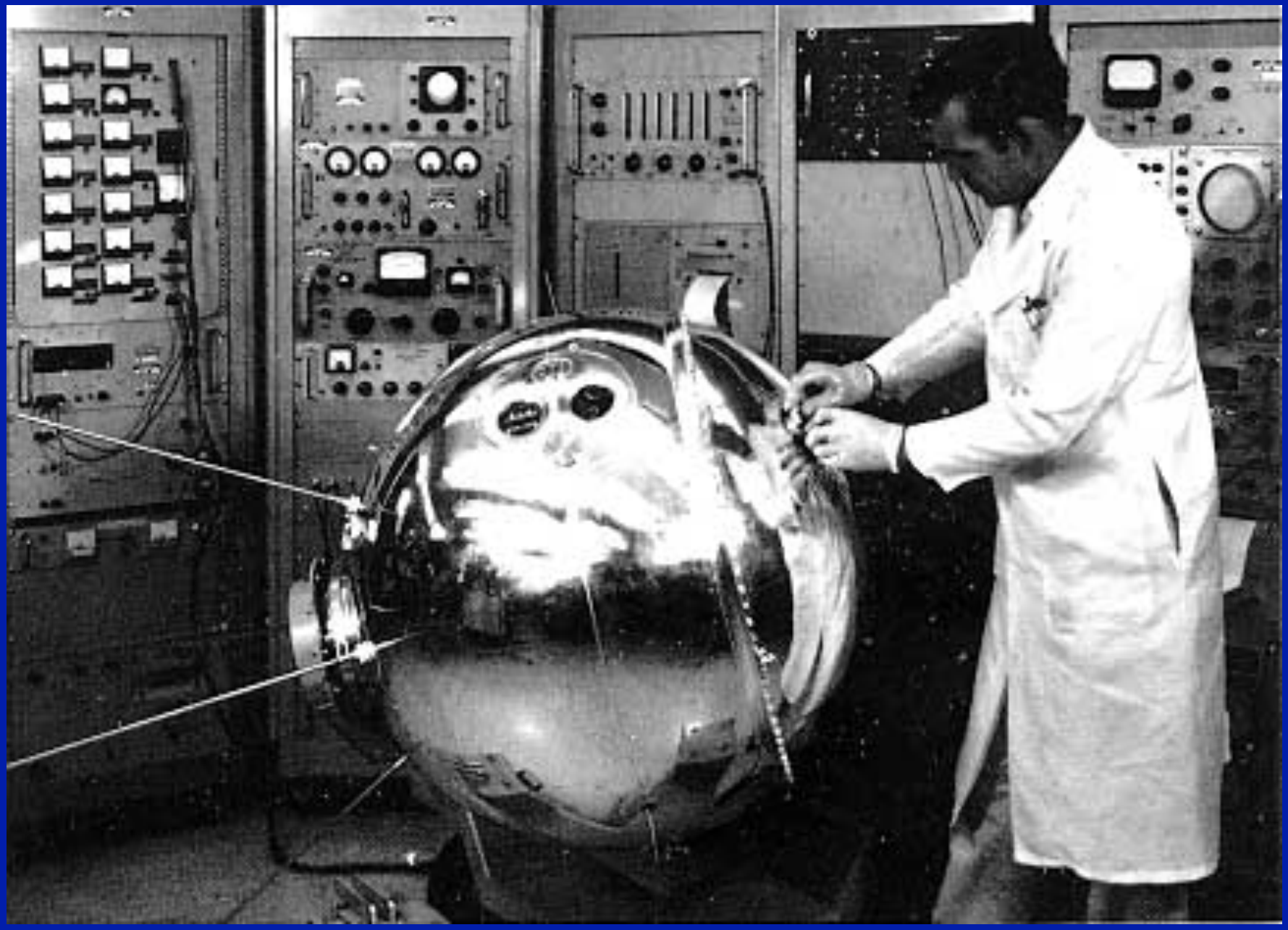
*Credit: ESA / ASI / UPD / OU / FMI*



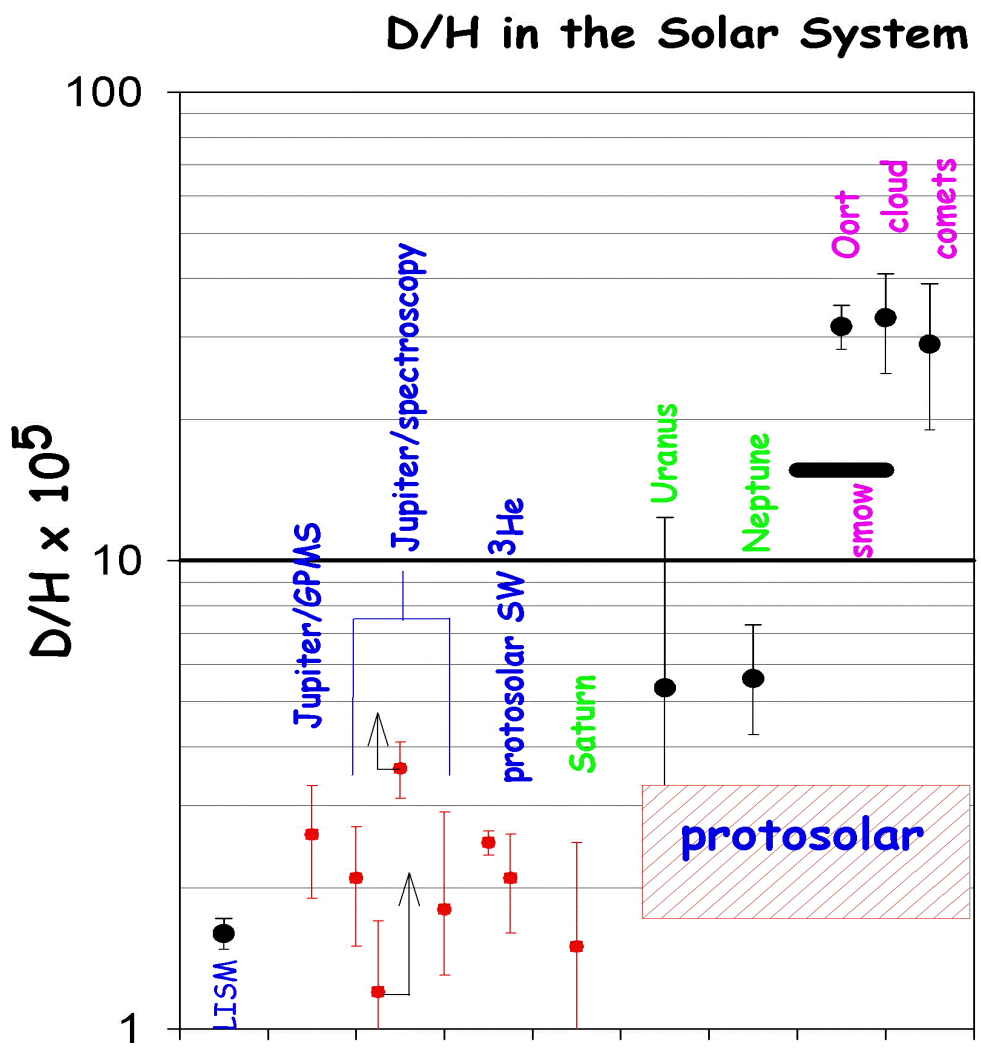
MG POOL

**Photo Credit: Nelson Spencer and NASA**

**The remains of a May 1949 V2 rocket flight.**



# Jupiter D/H Compared to Other Giant Planets and the Protosolar Value




GPMS $(D/H)_{Jupiter} = (2.6 \pm 0.7) \times 10^{-5}$
consistent with Voyager, ISO, and spectroscopic $CH_3D/CH_4$ measurements

GPMS $(^3He/^4He)_{Jupiter} = (1.66 + 0.05) \times 10^{-4}$
slightly higher than that found trapped in meteoritic samples ($1.5 \times 10^{-4}$)

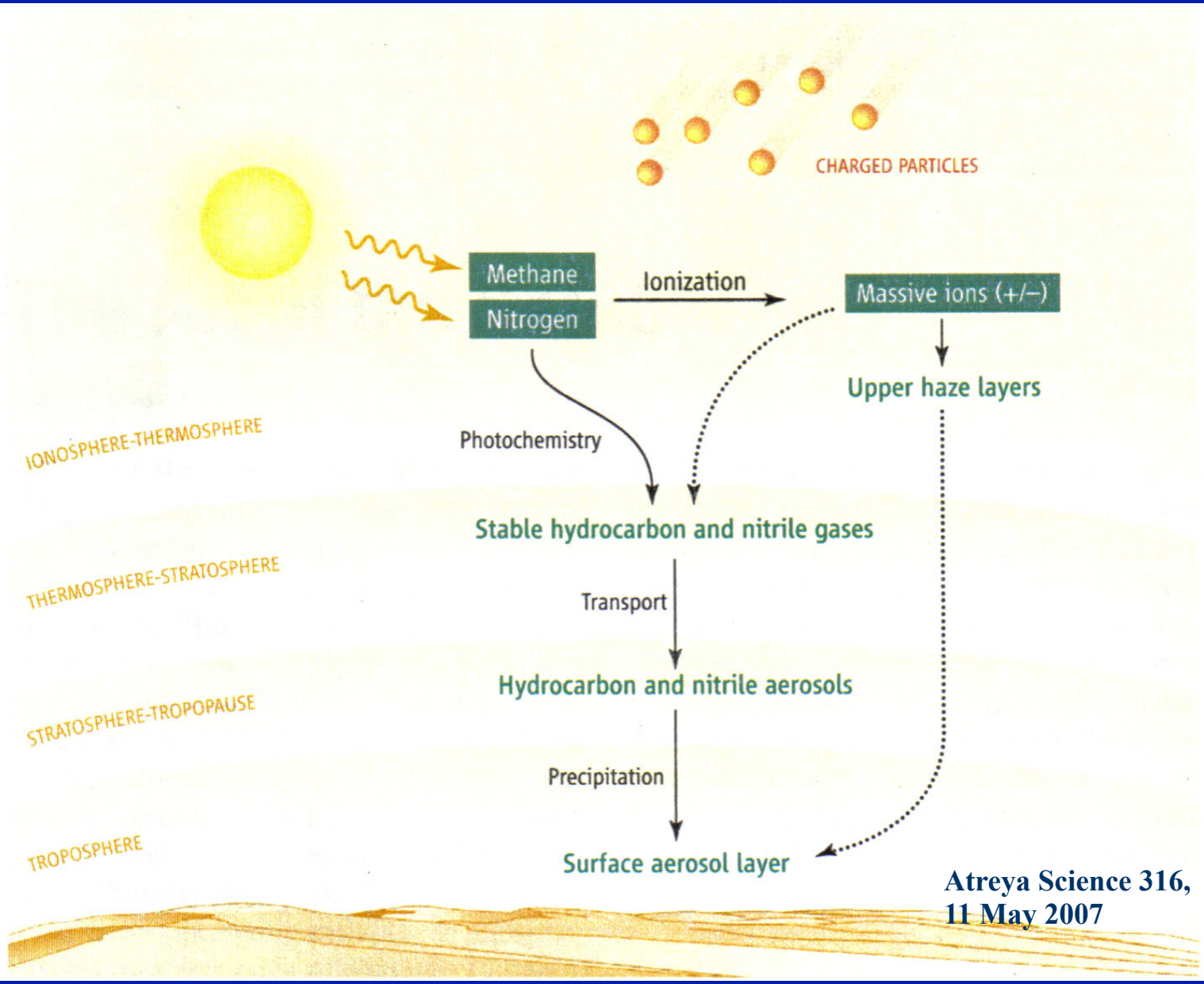
Agreement with protosolar D/H derived using GPMS $^3He/^4He$ and SW measurements

$(D/H)_{Jupiter} = (D/H)_{protosolar}$ . . . ratio is insignificantly affected by input from planetismals with higher (D/H)

Protosolar $(D + {}^3He)/H$ close to LISM

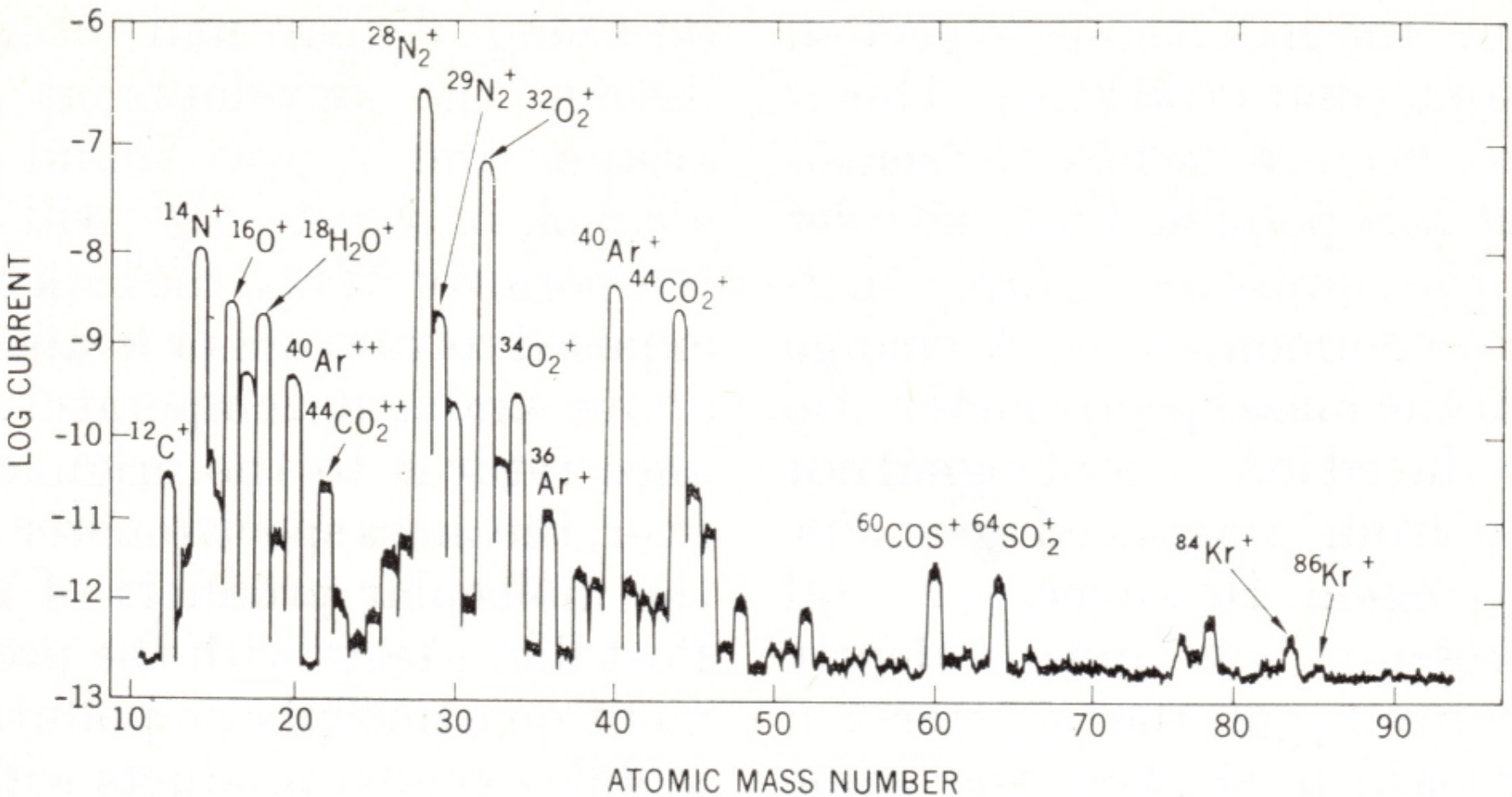
$10 \times (D/H)_{protosolar} \leq (D/H)_{Oort\ cloud\ comets}$
$(D/H)_{protosolar}$ as base for models of turbulent mixing in the early solar system, the origins of comets, and the formation of Uranus and Neptune

# Haze Formation on Titan




Atreya Science 316, 11 May 2007

# Planetary Atmospheres Experiment Test

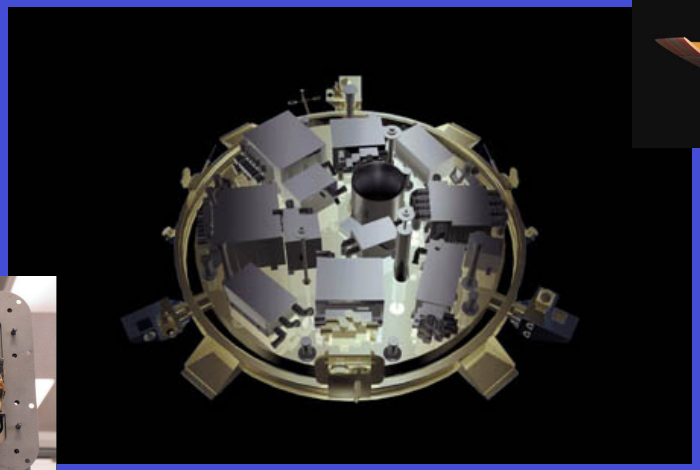


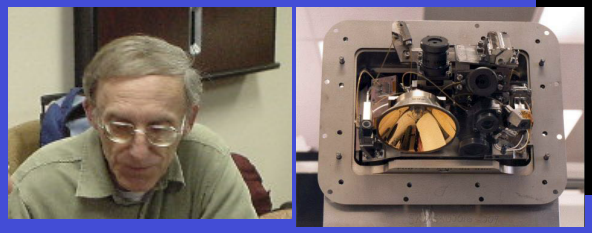
# The Huygens Probe Experiment(er)s

ACP

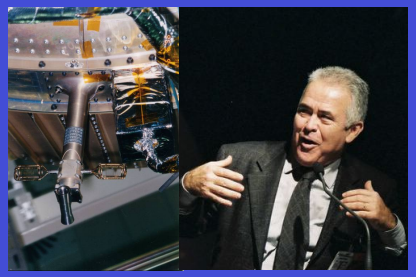
GCMS

DWE

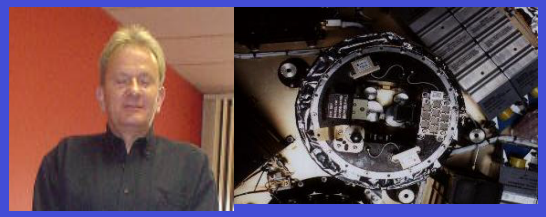




DISR



HASI



SSP

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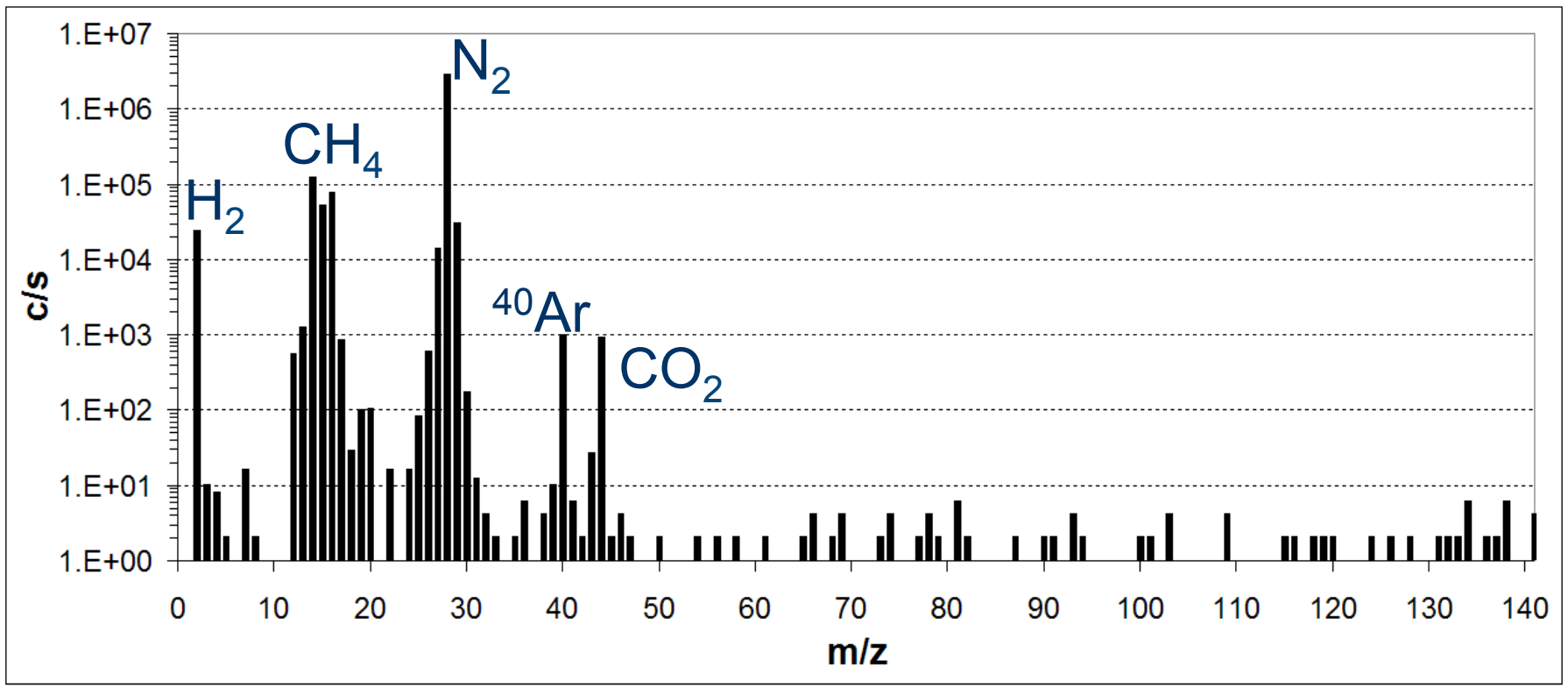
# Upper Atmosphere Averaged Spectrum (130-120 km)